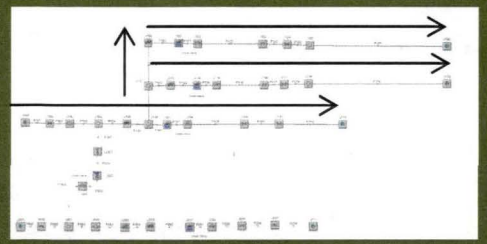
Liquid Hydrogen Regulated Low Pressure High Flow Pneumatic Panel AFT Arrow Analysis



Helium Operation

- Start - Starting inlet pressure at 2400 psig and exit pressures at 0 psig and 750 psig for initial startup.
- End – Used to determine the minimum inlet pressure that the panel will operate under.
- Pressure Drop Test - Used to validate pressure drops and flow rates through the system.

Project Definition: Design a high flow pneumatic regulation panel to be used with helium and hydrogen. The panel will have two circuits, one for gaseous helium (GHe) supplied from the GHe Movable Storage Units (MSUs) and one for gaseous hydrogen (GH_2) supplied from an existing GH_2 Fill Panel. The helium will supply three legs; to existing panels and on the higher pressure leg and Simulated Flight Tanks (SFTs) for the lower pressure legs. The hydrogen line will pressurize a 33,000 gallon vacuum jacketed vessel.

Pressure Drop Comparison

friction factor: $\frac{1}{\sqrt{f}} = 2\log(\frac{3.70}{\varepsilon})$

Velocity: $v = \frac{Q}{A}$

Q is the actual flow rate of the fluid:

$acfm = scfm(\frac{P_{standard}}{P_{actual}})$

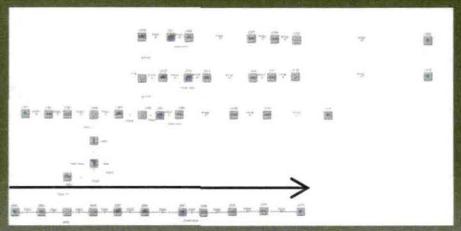
pipe head loss: $h_L = f\frac{L}{D}\frac{v^2}{2g}$

component loss: $h_L = K\frac{v^2}{2g}$; $K = \frac{890.3D^4}{{C_v}^2}$

Multiply the head losses by the density to get the delta pressure (psid).

$P_{out} = P_{in} - pipe\ loss - component\ loss - fitting\ loss - pump\ loss - elevation$

***Elevation, fitting (where the design is now), and pump losses assumed to be zero.

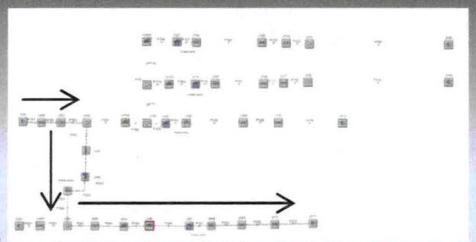


Hydrogen Operation

- Start - Starting inlet pressure at 4400 psig and exit pressures at 0 psig for initial startup.
- End – Used to determine the minimum inlet pressure that the panel will operate under.
- Pressure Drop Test - Used to validate pressure drops and flow rates through the system.

Parameters:

- 304/316 Stainless Steel Tubing
- Inlet Pressures:2400 psig (GHe) & 4400 psig (GH_2)
- Set Pressures: 750 psig;55 psig;40 psig (GHe) & 95 psig (GH_2)
- Temperature assumed to start and end at 70° F

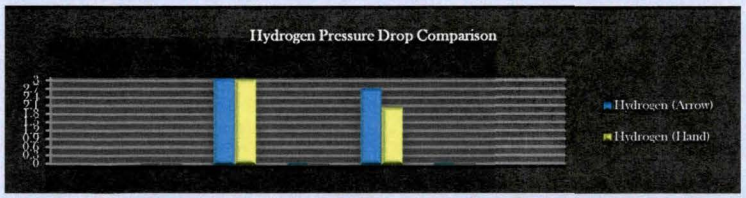


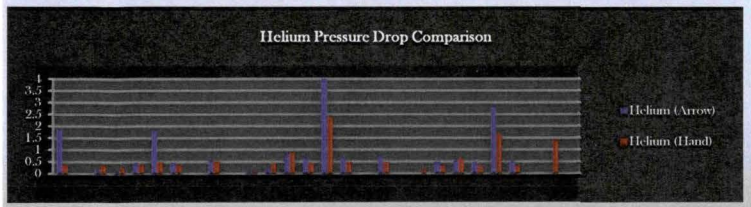
Helium Purge Operation

- Purge - Used to validate that adequate flow is purging the hydrogen line.

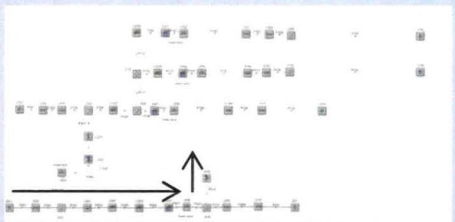
Outlet	Flow rate at maximum inlet pressure (scfm)	Flow rate at minimum inlet pressure (scfm)	Minimum Flow rate Requirement (scfm)
IRAS tank (GH_2)	1050.0	1486	350.0
SFT LH2 (GHe)	478.3	304.7	150.0
SFT LO2 (GHe)	642.3	346.9	150.0
Panels 79K06988 & 80K55275 (GHe)	970.3	1354.6	350.0

Flow rate Results





Temperature increases therefore pressure increases.



Failed Hydrogen Regulator

- Failed Regulator - Used to validate relief valve size if the regulator fails open.

Kelley M. Jones
NE-F2: Fluids & Propulsion Design Branch
NASA Kennedy Space Center
Kennedy Space Center, FL 32899